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AN ANALYSIS OF MULTI-ROLE SURVIVABLE RADAR TRACKING PERFORMANCE USING THE KTP-2 GROUP'S REAL TRACK METRICS

Willie D. Caraway III
Randy R. McElroy

Missile Guidance Directorate
Aviation and Missile Research, Development, and Engineering Center

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Abstract
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13. ABSTRACT ***(Maximum 200 Words)***

One of the outcomes of the 19th meeting of The Technical Cooperation Program (TTCP) Sub Group K Technical Panel KTP-2 was a set of track metrics [1]. The purpose of these metrics was to enable a qualitative comparison of the effectiveness of different radar tracking algorithms in the face of various target situations. The complex and highly variable target situations that radars face have made the development of a quantitative set of metrics that yield absolute scoring virtually impossible. These metrics now provide the radar engineer with a consistent basic upon which to compare the performance of various tracking algorithms. This report will detail the results of applying these metrics to data obtained during a Multi-Role Survivable Radar (MRSR) tracking test and presented at the 21st meeting of the KTP-2 group.

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I. INTRODUCTIONS

One of the outcomes of the 19th meeting of The Technical Cooperation Program (TTCP) Sub Group K Technical Panel KTP-2 was a set of track metrics [1]. The purpose of these metrics was to enable a qualitative comparison of the effectiveness of different radar tracking algorithms in the face of various target situations. The complex and highly variable target situations that radars face have long made the development of a quantitative set of metrics that yield absolute scoring virtually impossible. These metrics now provide the radar engineer with a consistent basis upon which to compare the performance of various tracking algorithms. This report will detail the results of applying these metrics to data obtained during a Multi-Role Survivable Radar (MRSR) tracking test and presented at the 21st meeting of the KTP-2 group.

II. TEST DESCRIPTION

The MRSR is an advanced development track-while-scan air defense radar developed by the U. S. Army Aviation and Missile Command (AMCOM). Near hemispheric search and track coverage are achieved using 360-degree mechanical rotation with phase steered elevation coverage. Tracking in the MRSR is handled by the Track Processor which is a self-contained software module within MRSR's Radar Data Processor (RDP). The inputs to the Track Processor are detection reports which come from the Dwell Management Processor, another self-contained software module within the RDP. The Track Processor is responsible for all track initiation and maintenance functions. Next scan location prediction and measured data smoothing are performed using an α-β track filter. When a scan fails to yield a detection with which to update a track, track coasting is performed using the previous prediction.

The data analyzed for this report were collected during an August 1994 tracking test. The target aircraft for this test was an F-86 equipped with a differential Global Positioning System (GPS) pod. This pod provided time-space truth data with 3m accuracy in the x, y, and z dimensions. The runs analyzed were all 3-g S-weaves flown radially with respect to the MRSR. A run is comprised of an outbound and inbound leg. Figures 1 through 3 show the GPS track data for each run and the corresponding MRSR track data.

An examination of the MRSR tracks for each of the three runs shows some notable and interesting differences between them. For Run 1, the tracking results are almost ideal with a single track covering essentially the entire run. Run 2 provides an excellent example of the bifurcation that often occurs in the MRSR tracker (tracks 88 and 76) as well as a single long track. For MRSR, bifurcation occurs when multiple detections on the same target fail to collapse to a single detection before entering the tracker. This causes the tracker to setup multiple tracks on the same target. Track segmenting is the distinguishing feature of Run 3. The MRSR data is composed of multiple segments covering less than 50 percent of the run. Due to the uniqueness of each run, the metrics were applied to each separately so that the effects of each tracking phenomena can be better understood.

III. TRACK METRIC ANALYSIS

The KTP-2 track metrics are divided into two groups depending on whether the track is real or false. Only the real track metrics were used for this analysis since no false tracks exist within the data set. For this analysis, the definition for each metric from Reference [1] will be given along with how the metric was applied to the MRSR data and the results obtained.

A. Track Initiation Delay

Definition: The length of time after the initial detection that it takes to report or display the track.

Implementation: The elapsed time from the first verifiable signal processor detection until a track on the target is reported.

Results: Due to a data recording glitch, no initiation data was recorded for Track 81 Run 1, Tracks 120 and 88 Run 2, and Track 73 Run 3. Tracks 48 and 76 Run 2 were range resolved and displayed on the first scan during which they were detected. Tracks 54 and 16 Run 3 were range resolved and displayed one scan after their initial detection which results in a 2-second delay. For this limited data set, track initiation delay can be deemed insignificant.

B. Track Life

Definition: The percentage of time the track is displayed or reported regardless of the number of track breaks or track number changes.

Implementation: The total time the target is displayed as a percentage of the elapsed time from the first track report on the target to the last track report.

Results: As can be seen from Figures 1 and 2, Runs 1 and 2 contain no intervals between the first and last track points without a displayed track. Consequently, their track life is 100 percent. Figure 3 shows two large track breaks over the course of Run 3 resulting in a track life of 77.6 percent.

C. Number of Track Numbers Associated with the Track

Definition: Trackers which drop and restart tracks without linking the segments (and do not maintain the same track number) should be heavily penalized.

Implementation: The total number of track numbers correlating to the target of interest for each run.

Results: For Run 1, MRSR maintained a single continuous track throughout the run so only one track number was used. During Run 2, the MRSR tracker experienced some light track segmentation as well as bifurcation resulting in the use of four track numbers. However, it should

be noted that two of the numbers are coincident with other track numbers as a result of the bifurcation. Run 3 is heavily segmented and consequently used three unique track numbers. The MRSR tracker contains no logic to attempt to perform track linkage, so by default, when track segmentation occurs it will perform poorly against this metric.

D. Number of Track Breaks with Constant Track Number

Definition: Trackers which contain breaks in a track but maintain track number continuity are penalized relative to one which has no breaks but is superior to one with breaks and changes in the track number.

Implementation: This metric is not applicable to the MRSR tracker since it makes no attempt to perform track linkage. Track segments with the same track number are a purely random event in the MRSR tracker.

E. Total Duration of Track Divergence

Definition: The percentage of total track life that the tracker output position exceeds the actual track position by some specified multiple of sensor resolution cells.

Implementation: The percentage of total track life that the tracker output position exceeds the actual track position by two standard deviations of MRSR's typical track accuracy (Section III.G.).

Results: As would be expected for a long track, Track 81 Run 1 has a relatively low divergence, only 21.2 percent, third lowest in the data set. Tracks 120, 88 and 76 Run 2 had divergences of 46.2 percent, 50.0 percent, and 100 percent, respectively. These results are not surprising given the short duration of these tracks and the fact that Tracks 88 and 76 are bifurcated tracks. Track 48 Run 2 has the lowest divergence of any track, 13.3 percent. This is consistent with its also being one of the longest tracks in the data set. Tracks 73 and 54 Run 3 have divergences of 20.0 percent and 42.9 percent, respectively. Track 54's divergence is consistent with the fact that it is a short track in the middle of a long turn. Track 73's divergence is the second lowest of the data set which is unexpected since it is a short track early in a maneuver. Track 16 Run 3's divergence of 36.4 percent is somewhat surprising given that this is a medium length track. Overall, the divergences are consistent with MRSR's intended role of providing cueing for a mid-course guided missile system.

F. Number of Divergent Tracks

Definition: The number of times that the tracker output position exceeds the actual track position by some specified multiple of sensor resolution cells.

Implementation: The number of reports that the tracker output position exceeds the actual position by 2 standard deviations of MRSR's typical track accuracy (Section III.G.).

Results: This metric is simply the numeric values used to compute the Track Divergence (Section III.E.). For Track 81 Run 1, this was 29 reports out of a total of 137. For Tracks 120, 88, 48, and 76 Run 2; it was 6 of 13, 4 of 8, 16 of 120, and 6 of 6, respectively. For Track 73, 54 and 16 Run 3; it was 3 of 15, 3 of 7 and 20 of 55, respectively.

G. Track Accuracy

Definition: The accuracy of the tracker output. This can only be determined for those cases where ground truth data is available.

Implementation: Global statistics for range, azimuth, and elevation errors were calculated using the longest track from each run.

Results: The global mean errors for range, azimuth, and elevation were -28.2 m, -0.20, and -0.31degrees, respectively. These errors are typically caused by bias errors between the origins of the radar coordinate system and the truth data coordinate system. The global standard deviations for range, azimuth, and elevation were 38.7 m, 0.27, and 0.59 degrees, respectively. These values represent the radar's typical track accuracy as mentioned in Sections III.E. and F.

H. Number of Track Swaps

Definition: Crossing targets can result in swapping of track numbers; tracking systems which have difficulties with these types of targets should be penalized.

Implementation: This test involved only one aircraft so no evaluation of this metric is possible for this data set.

I. Number and Percentage of Omitted Tracks

Definition: The total number of tracks which are completely missed by a tracker and that number as percentage of the total number of valid tracks in the data set.

Implementation: Given that this test involved only one aircraft flying profiles radially to the radar, this metric could not be properly evaluated.

IV. CONCLUSION

This report has presented the results of an analysis based on the KTP-2 Group's Real Track Metrics of MRSR's tracking performance against a maneuvering target. Overall, the MRSR's tracker performed well against a difficult target scenario. Over the entire test, the target was under track 92.5 percent of the time with sufficient track accuracy to support target engagement with a mid-course guided missile. The principle problem noticed during the analysis was track bifurcation for near-in targets. This problem is caused by a lack of track-to-track correlation logic within the MRSR tracker.

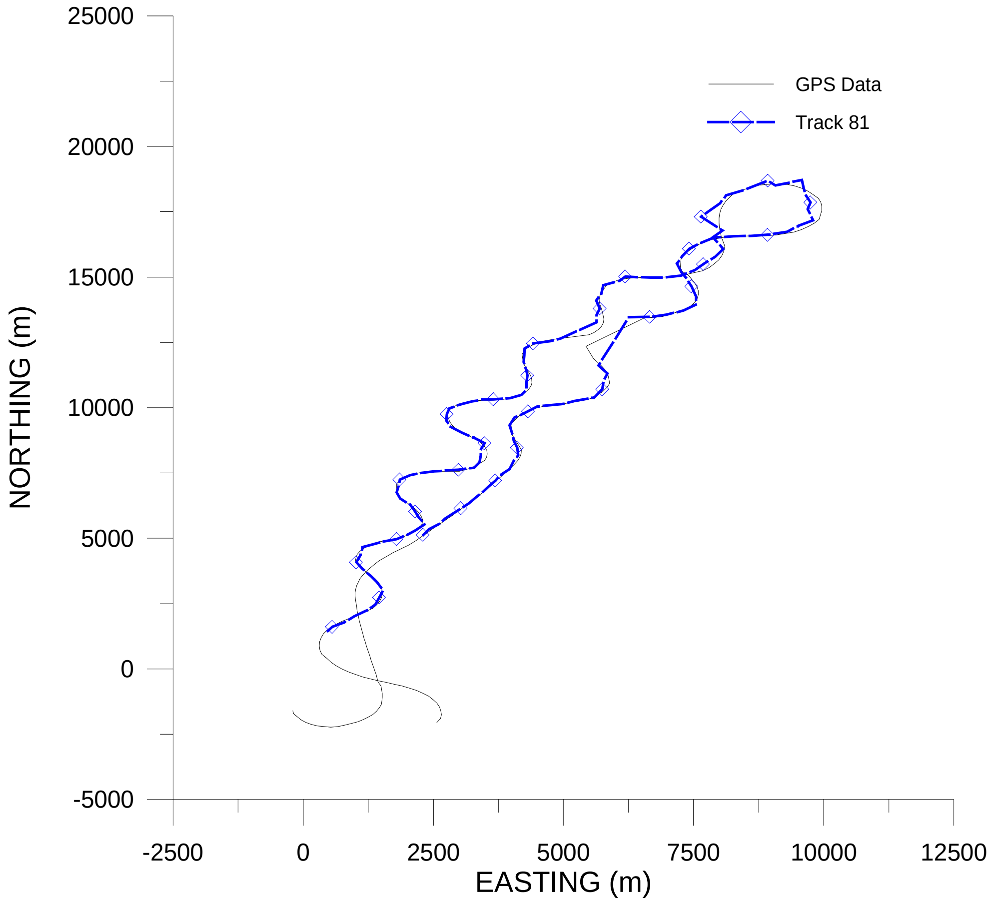

Figure 1. Truth Data and MRSR Track Data for Run 1

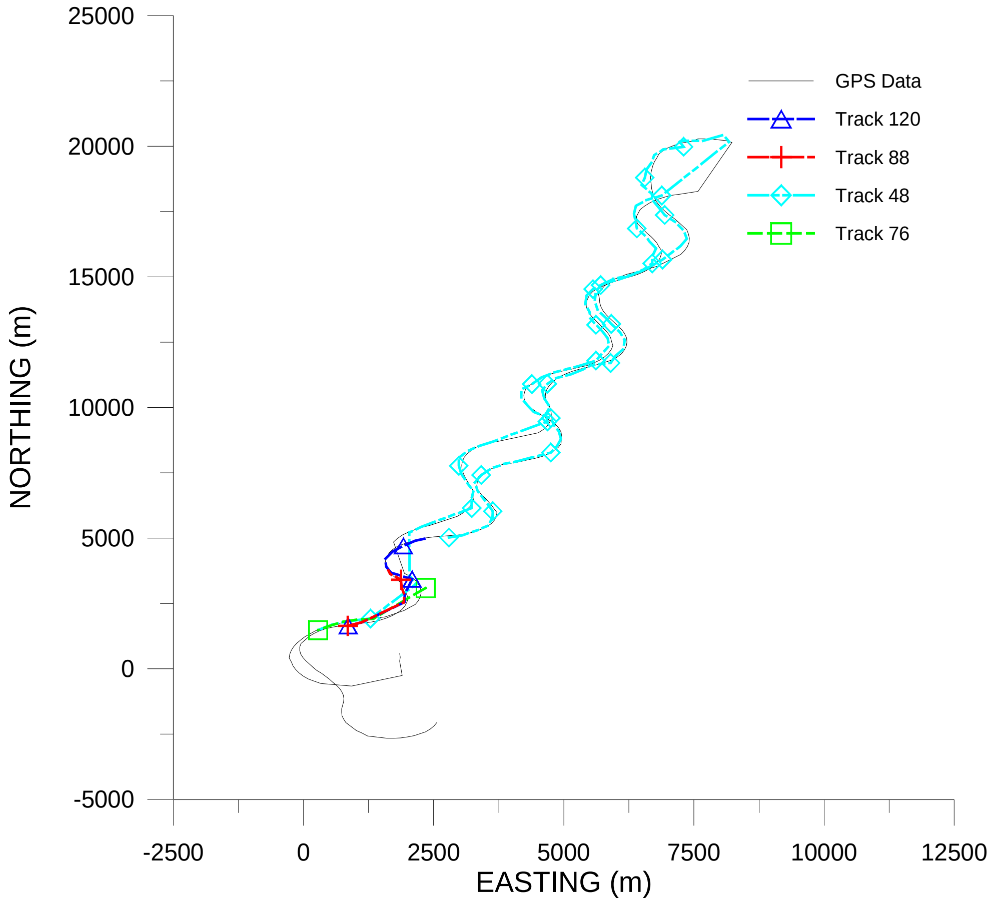

Figure 2. Truth Data and MRSR Track Data for Run 2

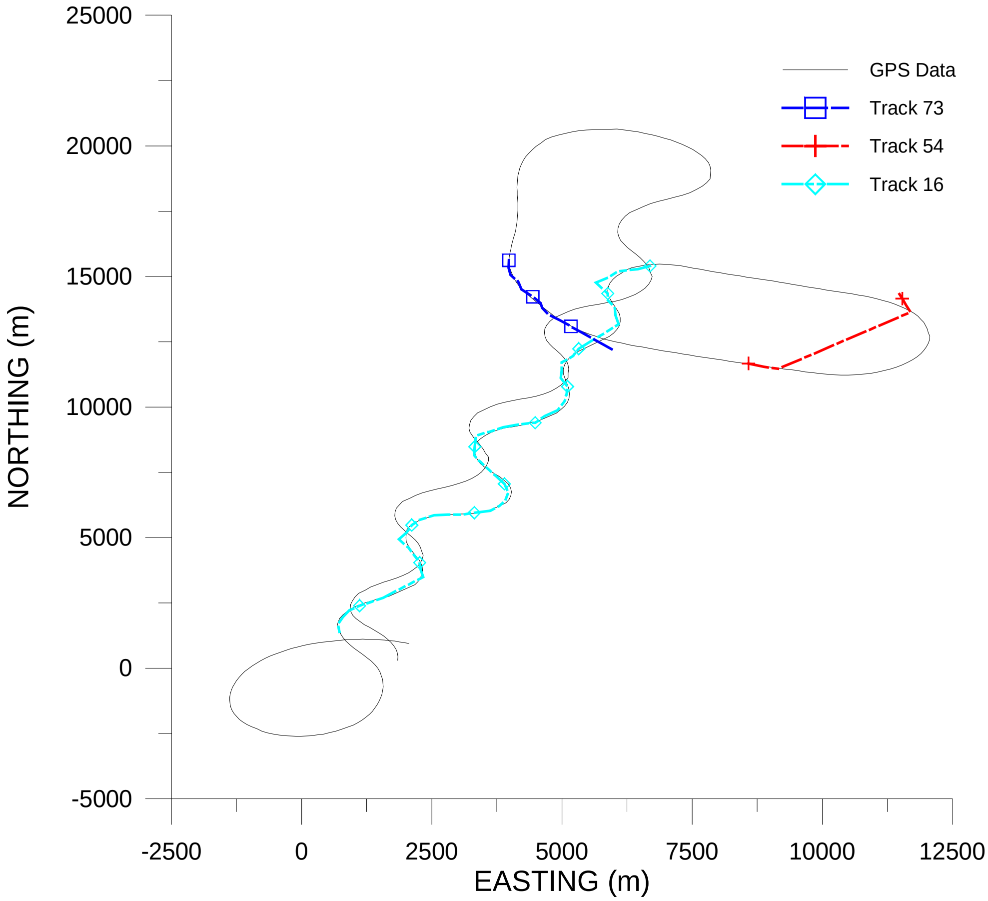

Figure 3. Truth Data and MRSR Track Data for Run 3

REFERENCE

1. "Minutes of the 19th Meeting (Volume 1: Business Meeting)", SUB GROUP K TECHNICAL PANEL KTP-2 RADAR DATA PROCESSING, July 1994.

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